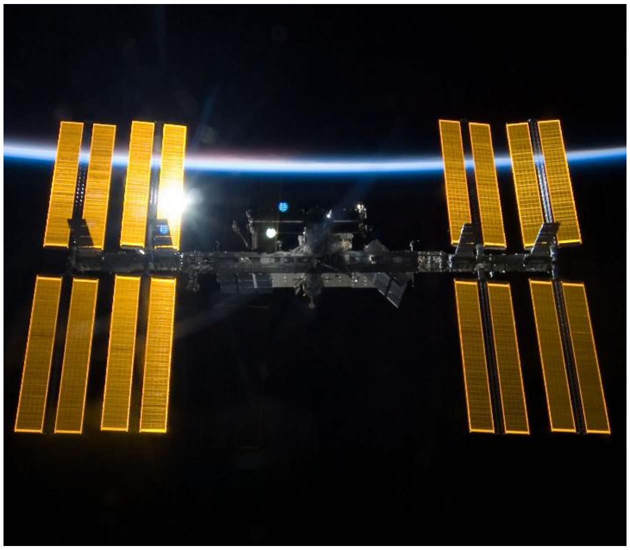

Figure 1. The International Space Station solar arrays lit up by the Sun.

National Mathematics Content Standards:

Number and operations

National Mathematics Process Standards:

Problem Solving

Mathematics Activity 1

Problem Solving: Saving Space Station Power

Objective

To calculate surface areas, then use solar array performance per unit area to calculate total power generation capacity. The goal is to apply these calculations to solve a scenario-based challenge.

Materials

Pencil
Paper

Background

The International Space Station (ISS) uses 8 large solar arrays, similar to the solar arrays used to power small calculators, but on a much larger scale. The area of the ISS is equal to nearly two football fields! They provide the power needed to keep the ISS running, keep the crew comfortable, and operate systems and experiments. They also charge sets of batteries that are used to store extra power. The solar arrays are attached to motors that move them to point at the sun as the ISS orbits around the Earth. When the Earth is between the ISS and the Sun, there is no energy produced by the solar arrays and all power is provided to ISS by the batteries.

In 2007, one of the solar arrays on the International Space Station was torn due to an issue with the deployment mechanism, as depicted in Figure 2. When issues like this occur, it is possible that the solar array might not generate as much power as it did prior to the damage. The real solar array was fixed after this happened and is back up to full power generation, but this real-life example is the basis for the thought experiment below.

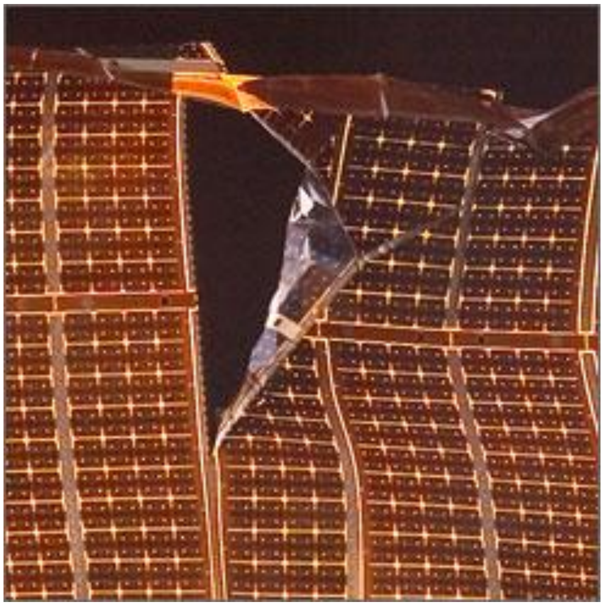

Figure 2. A torn solar array on the International Space Station.

NASA Challenge

You are in space as the Commander of the International Space Station, and one of your solar arrays has been torn by a damaged deployment mechanism. If you can not provide enough power, you might have to shut down science experiments onboard the International Space Station.

You need to figure out if you can still charge the batteries using this damaged solar array, by calculating how much power it produces.

Procedure

1. An undamaged solar array is a rectangle 12m wide by 34m long. Calculate the total area of the solar array.
2. You look out the window of ISS to assess the condition of the solar array. It appears that 10% of it has been damaged and will not produce power. Calculate the remaining usable area of the solar array.
3. If the solar array could produce 40 Watts of electricity per square meter, calculate the total number of Watts the damaged solar array can generate from the Sun. Round your answer to the nearest 100 Watts.
4. Mission Control tells you they need 9 (nine) kilowatts of power from this solar array in order to keep running ISS systems and science experiments. How much power is left to charge the batteries?

Extension

a. Assume that the ISS is in eclipse (in the shade of the Earth) 33% of the time during each orbit, and an orbit is 90 minutes long. During eclipse, the batteries do not get charged, and they also have to send out (discharge) 9 kilowatts of power to the science experiments. Do you have enough power to keep all of the science experiments running?
b. One of the motors that moves the solar array breaks, and you can no longer point the solar array directly at the Sun. If the solar array is pointed 45 degrees away from the Sun, how much power will it generate? Round your answer to the nearest 100 Watts. [hint: you will need the Cosine function for this]
c. After this happens, do you still have enough power to keep all of the experiments running?

Discussion and Answers

1. To calculate the total area of the solar array, multiply 12m times 34m.
   Answer: 408 m^2
2. If 10% is damaged, only 90% of the surface area is still usable. Multiply 408 m^2 times 0.9.
   Answer: 367.2 m^2
3. Multiply 367.2 m^2 times 40 Watts/m^2.
   Answer: 14,700 Watts
   (or 14.7 kilowatts)
4. Subtract 9 Kilowatts from 14.7 Kilowatts.
   Answer: 5.7 Kilowatts

a. The eclipse pass is 33% of the 90 minute orbit, so 0.33 x 90 = 30 minutes per orbit with no Sun and no battery charging. So the batteries are charged for the remainder of the orbit, 90-30 = 60 minutes, or 1 hour, each orbit.

   So the total amount of charge the batteries receive per orbit is 1 hour of charging times 5.7 kilowatts = 5.7 kilowatt hours.

   During the 30 minutes of eclipse the ISS systems and experiments are drawing 9 kilowatts for 0.5 hours, or a total of 4.5 kilowatt hours.

   Therefore each orbit the batteries are losing receiving 5.7 kilowatt hours of charge, which is more than their expenditure of 4.5 kilowatt hours of charge.

   Answer: Yes, the batteries are still receiving enough power to keep all experiments running

b. If the solar array is pointed 45 degrees away from the Sun, it will generate Cosine 45 times the original level of power generation. Cosine 45 = 0.53, multiplied by 14.7 kilowatts.
   Answer: 7.8 kilowatts

c. Similar to question 4, we need to determine how much charge the batteries are receiving if the systems and payloads are using 9 kilowatts of power. In this case, since the payloads are using more than the total amount of power avaialble (7.8 kilowatts), the batteries are not getting charged at all.

   Answer: No, there is not enough power to keep the experiments running. They will have to be turned off.